SWEET BRIAR COLLEGE
3 2449 0476936 2

Digitized by the Internet Archive
in 2010 with funding from
Lyrasis Members and Sloan Foundation

http://www.archive.org/details/differentiationb00mcca

Differentiated Instruction:
A Study of its Efficacy in the High School Physics Classroom

[illegible]
[illegible]

Differentiation by Interest:
A Study of its Efficacy in the High School Physics Classroom

Amy Bebko McCarty
Sweet Briar College

Table of Contents

Table of Contents i

List of Tables iii

Chapter 1 An Interesting Overview of Physics Pedagogy 1

Chapter 2 The Correlation Between Interest and Learning 5

Chapter 3 The Differentiation Plan 13

Chapter 4 The Results 18

Chapter 5 Future Improvements 29

Appendix A Chi-Squared Test on Class Averages 34

Appendix B Chi-Squared Test on Gender 35

Appendix C Chi-Squared Test on DIRECT Pre-Assessment Class Averages 37

Appendix D Summary of Possible Class Combinations 38

Appendix E Electrical Interest Survey 39

Appendix F First Differentiated Activity 41

Appendix G Interest-Based Review Questions 44

Appendix H Non-Interest Based Review Questions 47

Appendix I Student Interests Database 49

Appendix J Example Differentiated Worksheet 50

Appendix K Second Differentiated Activity 51

Appendix L Differentiated Group Problems 54

Appendix M Control Group Lab 64

Appendix N T-Test of Post-Assessment DIRECT Values 67

Appendix O Chi-Squared Test on Average Absences per Class Period 68

Appendix P Mann-Whitney U Test on Select Class DIRECT Scores 69

Bibliography 70

List of Tables

Table 1: Schedule of Lessons 14

Table 2: Differentiated and Non-Differentiated Activities 15

Table 3: Class Grade Average and Gender Summaries.......... 18

Table 4: Class DIRECT Pre-Assessment Summaries 20

Table 5: Summary of Selected Class Grouping.......... 21

Table 6: Schedule of Lessons 22

Table 7: Summary of Student Post-Assessment DIRECT Scores.......... 25

Table 8: Average Number of Days Absent per Student.......... 27

Chapter 1 An Interesting Overview of Physics Pedagogy

The challenge of engaging students in the study of Physics has long been recognized. In the late 1800's, Robert Millikan, the physicist who eventually was the first to identify the charge of an electron, began the modern process of reforming physics education. In the introductory physics courses that he taught at the University of Chicago he began to modify the format of the lecture hall and laboratory, placing more emphasis on the later of the two. He created, and then instructed from, a pedagogical textbook for high school physics teachers. This text focused on the general concepts, history and daily relevancy of physics that he believed should be taught at the secondary level (Millikan, 1950). Millikan's revisions to the curriculum were one of the initial evolutionary steps towards today's physics pedagogy.

The twentieth century saw a long line of physicists and physics educators leading the development of the secondary physics curriculum. In the first decades, classrooms had a strong focus on labs that were deemed prerequisites to university introductory physics courses (Swartz, 1991). Unfortunately, physics textbooks were still considered boring, as one physics teacher recalled:

> "Should there be another flood
> For refuge hither fly
> Though all around be wet
> This book will still be dry" (Peters, 1941)

Beginning in the 1930's American schools began to shift towards Progressive education, which emphasized the teaching of practical, daily applicable skills. This trend was manifested in high school physics classrooms through a shift away from

traditional physics content to the teaching of the mechanics of household appliances and automobiles. It was hoped that this shift would engage all students' interests, not just those that were college bound. After World War II, and the advent of the Cold War, the trend shifted again, this time back to a more traditional focus on the actual physical concepts, rather than their applications. This format was solidified by the curriculum that came out of the Physical Science Study Committee (PSSC). This group of physicists, led by Jerrol R. Zacharias of MIT, created a curriculum that focused on the philosophy and methods to investigate physics concepts (Donahue, 1993).

Within the past 25 years there has been much progress in the teaching of physics, with a growing body of evidence that supports what Milliken recognized over a century ago. Physics education has moved towards a more conceptual, active presentation of the topics, with less focus on formulas and simplistic applications, and more focus on developing explanations, teaching problem solving tactics and providing hands-on learning experiences (Knight, 2004). There are many different methods in current usage, but they are all focused upon the active engagement of students in the physics classroom.

Every one of the variations on interactive engagement in the physics classroom, has its own following of devotes. Although each group will attest to the superiority of their methods, research has made it apparent that any one of them is superior to the traditional lecturing methodology. In a wide ranging study of 6,000 college and high school students studying Newtonian Mechanics, the physicist Richard Hake found that that there is a strong positive correlation between the use of interactive engagement techniques and student performance on standard conceptual tests of Newtonian

Mechanics. He did not find that a particular form of engagement was superior to any other (Hake, 1998).

Current physics education research does attempt to take advantage of students' interest in the subject. It is important though to define interest. There are two different kinds of interest: individual and situational. Individual interest is that which develops gradually over time and is frequently tied in with life goals and values. Situational interest is spontaneously generated by one's environment and has little probability of affecting long term individual goals or values (Hidi, 1990). Often this later type of interest is termed curiosity. Current physics education, with its interactive engagement, focuses on the later of the two types of interest, situational. It seeks to engage students in the classroom, and gain their interest through an active method of presentation. Its goal is to pique their curiosity. It does not expressly attempt to engage students using their existing physics-related individual interests.

No widespread physics education methodology to date has attempted to directly address students' individual interests. Even progressive educational techniques did not try to cater to the individual students; rather it sought out topics which would interest all pupils. To use students' individual interests as a springboard from which to teach physics is very challenging. Frequently, students' pre-existing interests do not tie directly in line with academic goals, or are not as broad as the curriculum. Additionally, the interests of the students are not uniform, nor consistent. Even when a close correlation between student interest and curriculum is found, there still remains the challenge of demonstrating this relevance (Edelson & Joseph, 2001).

The implementation of lessons that are customized to individual student interests is called differentiation by interest. My research will investigate the correlation between aspects of a specific unit being differentiated by individual interest and student comprehension of the material. The hypothesis of this study will be that differentiation by individual interest in an unit on basic electrical circuitry will increase student comprehension of the material.

Chapter 2 The Correlation Between Interest and Learning

It has long been believed that interest influences how a person processes information – how they gain, retain and utilize it (Tobias, 1994). Over two hundred years ago, the German philosopher Johann Herbart recognized that students only learn what they are prepared to ascertain (Krapp, 2003). Later, John Dewey recognized the interplay between learning and interest when he wrote that the interaction between the two was when the "self and world are engaged with each other in a developing situation" (Dewey, 1913, n.p.). Modern research has confirmed these earlier suppositions by demonstrating the positive correlation between interest and learning.

We have already defined two forms of interest: situational and individual. The bodies of research concerning how interest influences learning can be divided into those studies related to individual versus those focusing on situational learning. This distinction is not explicitly recognized by many educational researchers, yet when it is superimposed on existing studies one is able to identify particular qualities of learning that are supported through the nurturing specifically of individual interests (Hidi, 1990). Learning in its most general sense is the acquisition of knowledge which leads to new capabilities (Howe, 1998). There have been many studies over the past 30 years which have explored different qualities and depths of learning. It has been found that appealing to students' individual interests can affect learning on multiple levels.

A fundamental characteristic of learning that many researchers have investigated is the acquisition of knowledge. Several studies have demonstrated a correlation between the accumulation of information and individual interests. In a 1973 study of

fourth graders carried out by Estes and Vaughan it was found that pupils remembered details from reading passages when they deemed them to be personally interesting. Similarly, in a study carried out in 1974 by Fransson, it was found that college students also recalled information better if they found it interesting (as cited in Hidi, 1990).

Comprehension of reading material requires a higher level of thinking than the simple retention of data. Several studies have found that student engagement, by appealing to individual interests, has increased this form of higher order processing. Asher and his colleagues found that fifth and sixth graders had a higher level of comprehension of topics that they found interesting. In 1988, Renninger found a similar increase in comprehension of mathematical word problems that were presented in the context of students' interests. Renninger found in her study of fifth and sixth grade math students that their individual interest in the subject directly affected their performance in the class (as cited in Hidi, 1990).

Students have been shown to persevere and try harder in the acquisition of new ideas when the topic is interesting to them. In 1988, Prenzel found that individuals who are interested in learning about computers will persist longer and attempt more frequently to learn computer activities (as cited in Hidi, 1990). This persistence has been found to help students stay focused on subsets of information that they found uninteresting, if they deemed the overall study to be personally interesting (Tomlinson, 2000).

Most of the research done on interest has been in reading and mathematics. Physics requires well developed skills in both of these areas. Hence, one may expect that similar to reading and mathematics, success in learning physics would be positively

correlated with interest in the subject matter. There have been a few studies that investigated the link between interest and student academic performance in physics. The combined results of eleven quantitative studies of 2522 students in physics classes ranging from the fifth to the twelfth grades between 1965 and 1984 found that there was a strong positive correlation between students' interest in physics and their grades in the class (Schiefele, 1992). Unfortunately, in these studies it is not clearly denoted as to whether situational or individual interest was evoked.

More recently, the correlation between individual interest and physics comprehension was researched by Perkins and colleagues. They studied over 750 college physics students at the University of Colorado, Boulder. This research made use of the Colorado Learning Attitudes about Science Survey (CLASS) in order to gauge students' interest in, and attitude towards, the sciences in general. The study found that a higher percentage of students who expressed a personal interest in physics completed the course. In other words, higher personal interest correlates with higher levels of perseverance in the field. This study also evaluated student recall and comprehension of mechanics through the standardized Force Motion Concept Evaluation (FMCE). It was found that there is a positive correlation between FMCE test scores and the level of students' personal interest (Perkins, Adams, Pollock, Finkelstein & Wieman, n.d.). This supports the conclusion that higher interest in a topic yields higher levels of comprehension.

All of the studies reviewed to this point deal with general student interest, not that which is unique to each individual. There is no research on unique individual student interest in the physics classroom, but there is some on this customized form of

instruction in other topics. Recognizing this stratified form of instruction as differentiation is becoming more commonplace in the educational psychology community.

Two studies of differentiation by interest that are useful to investigate in light of the currently proposed study are those done by K. Ann Renninger. She studied the correlation between differentiating by interest and the reading comprehension and mathematical word problem solving skills of fifth and sixth graders. The study of 222 students assessed their interest in 40 different topics, such as soccer, math, swimming, etc. The interest test used Likert-type questions that allowed students to self-assess their knowledge of, esteem for, and involvement in each activity. Likert-type questions are those that allow respondents to rank their response on a scale from most to least. Student interest in topics was then deduced from their responses. High interest was assumed to correlate with higher levels of knowledge, esteem for, and involvement in a particular area. Low interest in a topic was assumed to be demonstrated through low ratings for these three qualities. Students were also pre-tested, using topic-neutral questions to assess their knowledge of reading and mathematics. Individualized worksheets were then developed that were customized to each student's interests and skill level.

The differentiated worksheets in the reading portion of the study consisted of four structurally similar reading passages. Two were at the students' reading level, and two were above. Of each of the pairs, one was related to the students' interest, the other was not. Student comprehension was measured by analyzing what they wrote down

when asked to record everything they remembered from the passage after they had read it and no longer had access to it.

The study found that student recall was higher for reading passages that related to the students' interests, although this recall was not equivalent for interesting topics of different levels of difficulty. It was also found that girls both misread and recalled more details of their more challenging passages, while boys both misread yet recalled more details of their correlated grade level readings. Renninger interpreted this to mean that interest can serve to assist students in recall, but it can also serve as a distracter.

The differentiated worksheets in the mathematical word problem solving portion of the study were similar in nature to the reading test. They consisted of four structurally similar sets of problems. Two were at the students' level, and two were above. Of each of the pairs, one was related to the students' interest, the other was not.

For mathematical problems it was found that interest did not affect the correctness of student responses to problems at their academic readiness level. On the advanced problems it was found that girls had more difficulty setting up interesting problems, indicating that interest served as a distracter. On the other hand, boys were more successful at setting up the interesting problems, indicating that for them interest served as a motivator to persist (Renninger, 1992).

In light of this study, and the tools used to gauge student interest and achievement, we turn to the types of tools this investigation will use in the high school physics classroom. For the current study of the correlation between individual interest and the learning of high school physics, students will be administered an interests

survey, a pre-test and a post-test in electricity. Previous research and studies have created standards to be used in each of these forms of assessment.

In the study of interest in physics, the utilization of Likert-scale tests appear to be commonplace and generally accepted forms of measurement. The aforementioned CLASS requires students to respond on a five point Likert scale to 38 questions regarding their views on several aspects of math and science, including their related interests (Perkins et al., n.d). There were several ways in which this test was created to be valid as well as appropriate for students with varying science backgrounds. The questions were reviewed with field experts and students to ensure that they were clear and could only have one meaning. Only commonplace, not domain specific, vocabulary was utilized. After students took the test, the questions that were intended to similarly reflect student responses were evaluated to ensure that they did in fact closely correlate (Adams et al., n.d.).

Scoring a test based on a Likert-scale can be done one of two ways. Each score can be translated into a value and then responses can be summed or averaged. In other words, it assumes each response is equally weighted. Alternatively, it can be assumed that the responses are unevenly weighted, on an ordinate scale, and the translated value is a percentage of agreement. In the case of the CLASS, the ordinate scale was utilized since students had varying reasons for selecting a neutral response; hence it was not given any weight (Adams et al., n.d.).

The CLASS utilized a five point Likert-scale that ranged from strongly disagree, disagree, neutral, agree, to strongly agree. It was found that many students considered there to be a significant difference between agree/disagree and strongly agree/disagree,

such that if the scale was reduced to three points, they would select neutral, rather than strongly agree. Having a five point scale allowed students to agree, but not strongly. In scoring and evaluating the CLASS, with a small student population, researchers compressed the five point scale into a three point scale. This resulted in some loss of definition, but consistent results (Adams et al., n.d.).

There are many other studies which utilized a Likert-scaled test to evaluate students' interest in a topic. Renninger utilized such a test in her study of fourth and fifth graders and the correlation of differentiation by interest and readiness to reading comprehension and mathematical word problem solving capabilities (Renninger, 1992). Patricia Alexander and her colleagues used such a test in their studies of the correlation between students' interest and knowledge of immunology with their performance in physics. Her group used a ten point Likert-scale to measure student interests. On another test that her group led, they used a seven point Likert-scale to determine interest in immunology (Alexander, Jetton & Kulikowich, 1995). R.W. Skager and his colleagues studied the correlation between junior high school students' interest in each of their high school courses and their performance in each course. His three point test used terminology and referred to activities that were common to the students. His research found there to be a correlation between student interest and performance, but he also found there to be a tendency in students to answer the Likert-scale questions in the affirmative (Skager, Bussis & Schultz, 1965). The use of properly designed, custom Likert-scaled tests appears to be accepted in both the physics education and educational psychology communities as viable assessments of students' interests in topics and activities.

In order to test students' comprehension in electricity, there is not a great plethora of options. In fact, there is only one viable assessment at the high school level. This is the Determining and Interpreting Resistive Electric Circuit Concepts Test (DIRECT) (Engelhardt & Beichner, 1997). The DIRECT is not reprinted in the Appendixes per the request of its authors. The multiple choice DIRECT measures students' understanding of direct current (DC) resistive electrical circuits. Specifically, questions fall under the following categories: Physical characteristics of DC circuits, energy, current and potential difference. The versions 1.0 and 1.1 of this assessment have been found to be statistically reliable and valid. The test's reliability was confirmed with its high score on the Kuder-Richardson formula 20 (KR-20). The KR-20 is a measure of a test's internal consistency and overall reliability and can be used on tests that have questions that are scored right or wrong, are not influenced by speed and consistently measure the same topic or skill (Payne, 2003). In order for an assessment to be deemed reliable its score must be greater than or equal to 0.7. Version 1.1 scored exactly 0.7. The validity of the test was confirmed through reviews with experts as well as students to ensure that the questions were appropriate for the objectives and could only be interpreted the intended way. The creators of the DIRECT validated its efficacy as a discriminator between two groups of students who had received differing forms of instruction (Engelhardt and Beichner, 2004).

Chapter 3 The Differentiation Plan

My investigation into the correlation between students' individual interests and their ability to learn basic electrical concepts in the physics classroom was scheduled to occur within a larger seven week high school physics unit on electrostatics, electricity and electrical circuits at Amherst County High School, in Amherst, Virginia. There would be four classes involved in the study, each composed of about twenty students. These students would be a combination of eleventh and twelfth graders who had opted to take the course. It was not a class required for graduation.

The experiment was to be a comparison between two groups: One group received basic circuitry material that was differentiated by interest and the other group did not. Two of the classes would be the control group, while two would compose the experimental group. The classes would be selected so that there was as similar as possible male-to-female ratio, similar ranges of grades and pre-unit knowledge.

At the beginning of the unit I planned to administer the DIRECT to all of the students in order to measure the level of prior knowledge they held in DC circuits. All students would also be given an individual interest test that would be modeled after the Likert-scale surveys that are in common use in the study of interests within the educational psychology field. This test would be used to assess pupils' interest in topics related to electrical circuits such as home electrical wiring, automotive repair, home/auto stereo repair, conservation of energy, small appliance repair, historical applications and electrical appliance usage. All students would be told that the DIRECT and the Interest

test would be used so that I could tailor classroom instruction to their prior knowledge and interests.

All students would be given activities that made use of contexts that related to their interests in electrical circuits. In the experimental group, activities would be differentiated by interest. The individual students would be assigned activities that were specific to their stated interests. In the control group, student activities would not be differentiated by interest. All students in the control group would receive the same activities which either incorporated a variety of interests undirected towards specific student interests, or generic and not tied to actual interests.

Table 1: Schedule of Lessons

Day	Lesson Topic
1	Battery Lecture
2	Battery Review and Lab
3	Battery Review and Resistors
4	Resistor Color Coding Lab
5	Ohm's Law Part 1
6	Ohm's Law Part 2
7	Ohm's Law Lab Part 1
8	Ohm's Law Lab Part 2
9	Complex Circuits Ohm's Law Lecture
10	**Complex Circuits and Review**
11	Switches and Fuses Lecture
12	**Ohm's Law Lab**
13	Review for Quiz
14	Quiz
15	Review Quiz and take DIRECT

This unit was expected to take three weeks, or fifteen school days. There would be two differentiated activities that would be administered to the experimental group on days ten and twelve. On these particular days the control group would be given non-differentiated activities. Please see Table 2 for the specific activities.

Table 2: Differentiated and Non-Differentiated Activities

Day	Differentiated Activity	Non-Differentiated Activity
10	Interest Based Ohm's Law Review Sheet	Generic Ohm's Law Review Sheet
12	Interest Based Ohm's Law Group Lab	Non-Interest Based Light Bulb Lab

At the end of the unit I planned to re-administer the DIRECT to all of the students and compare the pre and post DIRECT differences in results between the control group and the experimental group. I expected to find in the classes differentiated by interest that these students would show a greater improvement on their DIRECT score, than students who did not have these learning experiences.

There are some important issues that I expected might skew the results, and it was necessary to acknowledge these and attempt to minimize them. It was expected that by giving students activities that were related to their interest then they would persevere longer with the concepts being taught and have better recall of the concepts. In the ideal testing environment, the control group would be given activities that were differentiated to their *disinterest* or simply were interest neutral. Due to the fact that the control and the experimental groups were expected to both be in the same school, there was a high probability that the students would discuss their class work. If it differed significantly, they might be able to discern that they were being tested. Students would not as easily be able to discern if half of the classes were being differentiated by disinterest. I did not think that student interest was going to be so strong in these topics that they would be able to discern every time that they are being given work that was aligned or not aligned with their interests. I also suspected that they would tend to focus more on being grouped (or not) with their friends. In spite of the fact that I believed it would be possible to differentiate by disinterest, I believed that it could be harmful to

students' acquisition of electrical circuitry concepts. Ethically, I did not feel right to do this to students.

There were several external threats that had to be considered. History could be a factor, but few outside influences were expected to alter students' understanding of electrical circuits in the three weeks over which the unit was taught. If a student did receive external training or instruction, I expected that they would show up as an outlier which might require that they be pulled from the set of students in the study. The students might mature, but due to the diversity of the classes, the age and the short time frame, I was skeptical that the classes would mature at drastically different rates. Additionally, the study of forty students for the control group and forty for the experimental group increased the number of subjects which it was expected would increase the probability that they would be equally diverse, making their average maturation the same. Similarly, selection maturation was hoped to be minimized due to the diversity of students in each class.

Some threats were not applicable to the current investigation. Instrumentation was anticipated to be quite consistent. Students were to be measured prior to the lesson and then afterwards by using the DIRECT, which eliminates subjectivity of evaluation on the teacher's part. Mortality, on a small scale could have minimal impact on the study. Students who fail to take the pre or post test would simply be removed from the study. If a large number of students were lost, it might change the statistical methods that were used to evaluate the results. This was not anticipated to be an issue. Regression to the mean was not expected to be an issue in this study, since

students were taking the same test twice. All students (control and experimental) would take the test pre and post unit so this threat would factor out in the analysis.

External threats might have presented themselves, but they would have been present in both the control and experimental groups. Hence, I did not think that reactive arrangement, testing treatment arrangement or multiple treatment interaction would affect my results. Selection treatment interaction would not come into play as long as the control and experimental groups were equally grouped.

I planned to evaluate the change in students' DIRECT scores using a one tailed t-test for independent samples. I would be evaluating the change in the pre and post DIRECT scores for the control and the evaluation groups. The null hypothesis was that differentiating by interest did not increase students' comprehension of basic electrical circuitry concepts. The hypothesis was that differentiation by interest increased students' comprehension of basic circuitry concepts taught in their physics class.

Chapter 4 The Results

Four high school physics classes were involved in this study of differentiation by interest within a unit on electricity. All of the classes were taught at the same pace. The course was in introductory algebra-based physics and was an elective not required for graduation. The classes were composed of eleventh and twelfth grade students.

The reality of the high school physics classroom can easily disrupt the most carefully laid plans. The control and experimental groups were selected based on comparing their pre-assessment test scores and current class grades, as well as considering gender ratios. Although the selection of the groups was very controlled, the execution of lessons in a high school classroom is seldom simple.

The grade averages and gender composition of these classes are detailed in the table below.

Table 3: Class Grade Average and Gender Summaries

1st Period			4th Period		
Grade	Average	82.44	Grade	Average	85.27
	Median	86.39		Median	91.06
	Skew	-0.93		Skew	-1.41
	Std Dev	12.21		Std Dev	15.33
Sex	Males	11	Sex	Males	13
	Females	9		Females	8
3rd Period			**6th Period**		
Grade	Average	86.87	Grade	Average	88.05
	Median	87.29		Median	90.11
	Skew	0.04		Skew	-0.52
	Std Dev	7.68		Std Dev	9.48
Sex	Males	5	Sex	Males	9
	Females	14		Females	9

The class averages as of March 1st, 2006 all lie between 82.44 and 88.05 percent. I ran a Chi-Squared test on the class averages in order to assess if the class

averages were dependent upon period. The Chi-Squared result of 0.21 (with 3 degrees of freedom at a 0.05 level of significance) is less than the critical value of 7.82. This supports the null hypothesis that the difference in class averages is not due to being in a particular period (see detailed results in Appendix A).

The gender distribution of the classes did not appear consistent. First and sixth periods appeared to be the two most balanced classes; third period had predominantly females and fourth had predominantly males. Two Chi-Squared tests, though, on the number of males and females in each class reveals that the differences in gender are not significant. The Chi-Squared test result on the number of females by class was 2.2, (with 3 degrees of freedom at a 0.05 level of significance) which is less than the critical value of 7.82. This supports the null hypothesis, that the different number of girls per class was not significant. Similarly the number of boys per class, with a Chi-Squared test result of 3.68, leads to the conclusion that the different number of boys per class was not significant (see detailed results in Appendix B).

The students were given the Determining and Interpreting Resistive Electric Circuit Concepts Test (DIRECT) before beginning the unit on Electricity. This test assesses students' understanding of light bulbs, switches, batteries and resistors in series and parallel circuits. Students were told that this was a pre-assessment to find out what they knew about electricity. Their answers were recorded on a Scantron sheet. This test proved to be very difficult for most of them and they were assured that it would not affect their grade, that it was informational only. They were instructed to make educated guesses where possible, but if they did not have any understanding of a question to leave it blank. The DIRECT has twenty-nine questions.

Table 4: Class DIRECT Pre-Assessment Summaries

1st Period		4th Period	
Average	5.83	Average	4.95
Median	7.00	Median	4.00
Skew	-0.48	Skew	0.81
Std Dev	3.17	Std Dev	3.63
3rd Period		**6th Period**	
Average	3.47	Average	4.44
Median	2.00	Median	4.00
Skew	0.43	Skew	0.44
Std Dev	3.32	Std Dev	2.92

The summaries of the average number of correct responses by class period are shown in Table 4. It is apparent that the students did not bring a large amount of previous basic circuitry knowledge to the class. Additionally, a Chi-Squared test of the class averages on the DIRECT results reveals that there is no significant difference between the pre-assessment results in each class. I had to accept this null hypothesis because the test result was 0.63 (with three degrees of freedom at a 0.05 level of significance), which is less than the critical value of 7.82 (see detailed results in Appendix C).

This experiment designated two classes as the experimental group, and two as the control group. I have shown that based on Chi-Squared test results there was no significant difference in the grades, pre-assessment scores or gender ratios of the classes. In order to strive to make the test as equitable as possible, the classes were selected to have as similar groupings as possible.

Table 5: Summary of Selected Class Grouping

1st and 6th	**DIRECT**	**Grade**
Average	5.18	85.10
Median	5.00	88.63
Skew	-0.04	-0.90
Std Dev	3.09	11.22
Males	19	
Females	19	
3rd and 4th	**DIRECT**	**Grade**
Average	4.29	86.03
Median	3.50	89.90
Skew	0.65	-1.49
Std Dev	3.53	12.18
Males	18	
Females	22	
Difference Between Pairs	**DIRECT**	**Grade**
Average	0.89	-0.93
Median	1.50	-1.27
Skew	-0.69	0.59
Std Dev	-0.44	-0.96
Males	1	
Females	-3	

The paring of first-sixth and third-fourth periods ended up being the most equitable grouping since it had a small DIRECT score difference between the pairings (0.89 points) and the smallest grade difference of all of the possible pairings (0.93%). Additionally, this grouping appeared to be the most favorable due to the fact that it had the least total gender differences between the groups. Hence, first and sixth periods were selected to be the experimental classes, while third and fourth periods were selected to be the control groups. Please see Appendix D for a summary of all three of the possible class combinations.

Prior to the commencement of the unit all students were administered a questionnaire to assess their interest in topics related to electricity. The topics were based on practical applications that use electrical circuits – from student interest in how

computers work to how pacemakers work. They were asked to rate their interest on a five point Likert scale that ranged from Very Interested, Interested, Don't Care, Uninterested, to Very Uninterested. The questions were read to the students and they wrote their responses down. Students were deemed interested in a topic if they responded Very Interested or Interested in a topic. Please see Appendix E for the Electrical Interest Survey that students were administered. All responses were saved to a Microsoft Access Database. Student responses were used as a source of topics by which to differentiate.

The unit on batteries, bulbs, resistors, switches and circuits lasted for three weeks and was a subunit of the larger electricity unit. All classes were presented with the same material with the exception of two differentiated activities that were presented only to first and sixth periods on Friday, March 10th and Wednesday, March 15th. The schedule that was adhered to is detailed in Table 6. First period had a slightly different schedule than third, fourth and sixth periods. This is shown in the table.

Table 6: Schedule of Lessons

Day	Date	Event	Lesson Topic (Pd. 1)	Lesson Topic (Pds. 3,4,6)
Mon.	2/27/06		Battery Lecture	Battery Lecture
Tues.	2/28/06	1st Pd –Assembly	No Class	Battery Lab & Review
Wed.	3/01/06		Battery Review and Resistors	Battery Review & Resistors
Thurs.	3/02/06		Resistor Color Coding Lab	Resistor Color Coding Lab
Fri.	3/03/06		Ohm's Law Part 1	Ohm's Law Part 1
Mon.	3/06/06		Ohm's Law Part 2	Ohm's Law Part 2
Tues.	3/07/06	Extended 1st Pd	Ohm's Law Lab Part 1 & 2	Ohm's Law Lab Part 1
Wed.	3/08/06	Extended 1st Pd	Battery Lab	Ohm's Law Lab Part 2
Thurs.	3/09/06		Complex Circuits Lecture	Complex Circuits Lecture
Fri.	**3/10/06**		**Complex Circuits & Review**	**Complex Circuits & Review**
Mon.	3/13/06		More Cmplx Circuits & Review	More Cmplx Circuits & Review
Tues.	3/14/06		Switches & Fuses Lecture	Switches & Fuses Lecture
Wed.	**3/15/06**		**Ohm's Law Lab**	**Ohm's Law Lab**
Thurs.	3/16/06	Senior. Breakfast	Review for Quiz	Review for Quiz
Fri.	3/17/06		Quiz	Quiz
Mon.	3/20/06		Review Quiz & take DIRECT	Review Quiz & take DIRECT

The first experimental lesson occurred on March 10th as part of the lesson on Complex Circuits and Review. The differentiated activity was a set of custom practice problems that were administered to the experimental group. The control classes were given a set of generic review problems. The second lesson, Ohm's Law Lab, on March 15th involved complex word problems that were differentiated by interest for the experimental group, and a lab on light bulbs for the control classes.

The differentiated Complex Circuits and Review activity that was given to first and sixth periods was a seven question add-on to the students' general batteries and resistors review sheet. These seven questions were customized to seven specific interests in electricity that students had expressed in their Electrical Interest Survey (Appendix E). The topics used for this activity were telephones, cars, stereos, lasers, computer hardware, history of inventions and small appliances. Students who expressed an interest in a topic were given a question in the context of it, while students who were not interested were given a generic question that did not directly relate to any real world applications. Please see Appendix F for this activity's lesson plan. The generic questions (see Appendix H) and the interest-based questions (see Appendix G) were of the same level of difficulty and of the same electrical circuitry concepts.

The customization of each review sheet was facilitated by the storage of student interests in an Access database (see Appendix I for the specific tables and table structure used). The interest-based and generic questions were entered into database tables, and worksheets specific to each student were automatically generated based on their interests saved in the database. Please see Appendix J for an example of a differentiated worksheet that was created using the database.

First and sixth periods were told that the seven questions were based on their interests and that all students' problems were equitable in difficulty. Third and fourth periods were given the seven generic questions. At no time did the two pairs of classes indicate that they realized that the sets of classes were given different groups of problems – differentiated and undifferentiated.

The second experimental lesson occurred on March 15th. The differentiated activity was a set of problems students were assigned to work on in groups, according to a particular interest of theirs that had been denoted on the Electrical Interest Survey. The three topics used were lasers, stereos and car repair. Each activity was as close to realistic as possible, while utilizing only circuitry concepts from the unit. Please see Appendix K for this activity's lesson plan and Appendix L for the actual differentiated problems the students were given.

The control classes were given a lab that investigated light bulbs in parallel and series (see Appendix M), instead of the differentiated activities. This activity was similar to the differentiated activities in that it dealt with resistors and light bulbs in series and parallel. As with the first activity, there was never any indication from the students that they realized the classes were being given different tasks.

The students took their quiz for the unit on Friday, March 17th, the final day of the unit. The following Monday, after reviewing their quizzes they were given the DIRECT again. In order to ensure students would focus and do their best on the assessment, all classes, experimental and control, were given one fourth of an extra credit point towards their grade on the unit quiz for each question they answered correctly. There was great improvement in the DIRECT scores across all of the classes.

Table 7: Summary of Student Post-Assessment DIRECT Scores

1st Period		4th Period	
Average	12.19	Average	13.25
Median	11.50	Median	12.00
Skew	0.55	Skew	0.68
Std Dev	4.20	Std Dev	4.49
3rd Period		**6th Period**	
Average	10.88	Average	11.44
Median	10.50	Median	11.00
Skew	0.07	Skew	0.31
Std Dev	3.18	Std Dev	3.22

The marked improvement may be attributed to the students' learning about circuits. In addition, since the post-test afforded the students extra credit, they may have been more willing to make educated guesses, or even random guesses, than they were on the initial assessment.

An independent single tailed t-test comparing the difference between the pre and post assessment values of the control and experimental groups was performed. The t-value with 64 degrees of freedom and a 0.05 level of significance was 1.482. The critical value of a one-tailed t at 60 (a conservative degree of freedom, since 64 is not available) is 1.671. The obtained value is less than the critical value; hence I could not reject the null hypothesis. Please see Appendix N for the detailed t-test data. The results show that there was no statistically significant difference between the scores of the experimental and control groups. This experiment was unable to demonstrate that differentiation by interest results in increased learning of basic electrical circuit concepts. There are several factors that introduced threats into this study, which should be addressed. Variations in the populations, differing instructors and schedules all could have affected the outcome of the study.

The class pairings into control and experimental groups, although academically and in gender count very similar, resulted in the personalities of the classes being unbalanced. First and sixth periods are calm classes, with minimal disciplinary issues. Each of these classes had relatively equal numbers of males and females. Third and fourth periods are more active, kinesthetic groups, who engaged in frequent off-topic discussions. Third was predominantly female, while fourth was predominantly male. The learning environments of these classes are different due to the variations in makeup and general behavioral characteristics of the classes. These differences could have an effect on students' ability to retain material, and could have influenced the results of this study.

Class schedules were not consistent throughout the study. On Tuesday of the initial week, there was a school assembly and no first period class. On Tuesday and Wednesday of the second week there was an extended first period, which took all juniors out of class in order to take their SOLs. The first period extension caused all of the other periods to be shortened. This resulted in the instructional time of periods three, four and six to be broken across days. On the last Thursday of the unit, the day before the quiz, there was a "Senior Breakfast." This is an event for seniors which allow them to leave their first period class. This day was a review period for the quiz which all first period seniors missed. Due to the multiple inconsistencies in schedules first period ended up doing their battery lab (which emphasized the effects of batteries in parallel and series) at the end of the unit rather than at the beginning when the material was initially presented. All of the other classes did this lab at the beginning of the unit.

Please see Table 6 for the detailed schedule of all of the lessons. This variation in schedule could have affected students' ability to learn the material.

All topics except complex circuits were taught consistently across the classes. For this particular topic, the mentor teacher taught third period the complex circuit lessons. The mentor teacher taught complex circuits differently then I did and this could have affected students' comprehension of circuits. It is important to note though that the DIRECT does not deal directly with complex circuits.

In all of the classes, there was a high number of absent students due to a flu bug that swept through the school. The average number of absences per student throughout the duration of the unit is shown in Table 8.

Table 8: Average Number of Days Absent per Student

Period	Days Absent
1	1.75
3	1.58
4	1.2
6	1.61

A Chi-Squared test on these averages resulted in an obtained value of 0.11, with three degrees of freedom and a significance level of 0.05, which is less than the critical value of 7.82. This result revealed that the average number of absences in each class were not significantly different from one another (see detailed results in Appendix O). Therefore, I assumed that the affect of absenteeism was equally deleterious to all periods, and did not consider it to have any greater affect on the results of one class over another.

In sum, it is apparent that first and third periods possibly had threats introduced into their schedule and instruction respectively and had treatments that were dissimilar from those of the other classes. Fourth period, one of the control classes, and sixth

period, one of the experimental classes, had the most similar instruction and schedules. In order to see if the variation in treatment affected the results of the experiment I re-evaluated my results, using only these two similar classes.

Interestingly, the mean score improvement for period four (non-differentiated) is *higher* than the mean score improvement for sixth period (differentiated). This seemed to be pointing to the possibility that not differentiating by interest improved students learning. To see if there was any difference between the two classes I used a two-tailed Mann-Whitney U test for non-parametric statistical significance. The obtained P-value that I calculated for this test was 0.377, where $n_1 = 20$ and $n_2 = 14$. This obtained P-value is much greater than the 0.05 level of significance. This test leads me to conclude that there is no significant difference in class results. I cannot reject the null hypothesis that these two groups' scoring improvement is independent of class. Hence, this study is left with the conclusion that differentiation by interest does not impact students' abilities to learn about light bulbs, resistors, batteries, switches and circuits.

Chapter 5 Future Improvements

In my study of differentiating by interest within an introductory physics unit on basic circuitry there were many unexpected challenges, and many aspects of it that could be refined in future experiments. The study was made up of a control group, composed of two classes, which did not have any differentiation by interest in its lessons, and an experimental group composed of two classes that had two lessons differentiated by interest. The students' learning was evaluated by the improvement in their responses on the DIRECT. The DIRECT is a standardized basic electrical concepts test. An initial evaluation of the two groups found that there was not a difference in the results of the differentiated versus the non-differentiated classes. It was recognized that there were many threats to the validity of the study, and so the evaluation was narrowed to the two most similar classes – one differentiated and one not differentiated. The comparison of these two similar classes did not result in significant findings. There continued to be no significant difference between the achievement of the control and the experimental classes. In retrospect there are many facets of this study that could be changed in order to refine and strengthen the validity of the findings.

The most conspicuous improvement needed for the study would be to minimize variations in lecture presentations and class scheduling. In this experiment, first period, one of the experimental groups, had several extended class periods which shortened the other classes' periods. Additionally, there were two school functions that took the majority of students from this class. These variations in class schedule and time are a

threat to the validity of the study as all control and experimental groups do not share the same history. Similarly threatening, during third period, one of the control classes had a different history than the other classes because another teacher taught some of the lessons in the unit.

In future studies, the impact of scheduling and instructional variations to the study should be minimized. This is difficult to do since the unit spans three weeks, and controlling class schedules is frequently difficult. Increasing the sample sizes would help to minimize the impact of history on either group. This could be done by executing it over several years and across several schools.

It is difficult to overestimate the challenge of differentiating by interest within an introductory circuits unit. At this level students are just acquiring the fundamental terminology and concepts. This content is seldom advanced enough to apply directly to real world applications. Also, it is difficult to tie the concepts directly to student interests, due to the fact that these applications frequently require an understanding of other electrical circuitry concepts which have yet to be acquired. The challenge of differentiating by interest is to ensure that the activities are authentic, yet achievable.

This study, with its two differentiated activities was halfway successful in creating authentic, yet achievable, tasks. The first activity, a customized review sheet that had interest-based questions that were unique to each student was authentic, and achievable. It was challenging for students, but they were successful in completing it. The second differentiated activity was authentic, but unfortunately was not achievable by most of the students. The activities involved realistic problems related to auto mechanics, lasers and stereos. Although the students had the skills to complete the

activities, they were not ready for this level of application. In the future, these group activities need to included more scaffolding to help the students see the correlation between their new circuitry knowledge and the interesting activities they are assigned.

An additional difficulty in this study, similar to developing appropriately challenging differentiated activities, was finding equally challenging non-differentiated activities for the control group. This was very easy in the review questions; they simply had non-differentiated questions that were not tied to actual applications that could pique interest. This proved to be more challenging in the interest based activities. The control group was given a lab on light bulbs in parallel and series which may have provided them more reiteration of fundamental concepts than the differentiated groups received. It would be important in future studies to find non-differentiated tasks which are more task-similar to the experimental group's tasks, in order to minimize maturation effects.

The strength of the students' interests that lessons were differentiated by may have had an impact on the results, if in fact they were not actually strongly held interests. The determination of students' interests was done through a simple questionnaire, asking them to rate their interest in learning about particular topics. It may have proven valuable to ask students about activities that they engage in, in order to determine the strength of their interest. If students merely are curious about something, versus independently pursuing information about a topic, this will reveal varying levels of interest. Tying into stronger, deeper interest may have more of an impact on students' learning. It would be helpful to refine the interest assessment in order to better understand the strength of students' individual interests.

In both the control and experimental groups the lessons were taught showing the correlation between classroom instructions and real life. For example, all students learned that it is important to know how much power will flow through a resistor, because if they use one that is rated for less power than it actually sustains, it can burn up. Students were then given the example of wiring a car amplifier which, if done with resistors that have too low of a power rating, can cause a fire and destroy the equipment. In an ideal study, these real life examples would be presented only according to the students who are expressly interested in such topics. In reality, it is important to share these real life details with all students, as it demonstrates real world applicability and may stimulate new student interests in electricity related topics. I do not feel that general lessons tying into student interests should be eliminated from the classroom, in spite of their impact on the study.

In future studies it would be beneficial to increase the number of differentiated activities. If more activities were designed, even to the extent that the entire unit was differentiated, one may have a better chance of tapping into students' interests in order to motivate their learning. This would be a challenge, though, since there are still basic concepts that take a majority of the three week unit to cover. The time constraints that the physics classroom brings with it made it difficult to spend much time differentiating. Perhaps in an electronics class, where more time can be spent on applications, a study of differentiating by interest could be carried out that included more interest-based activities.

The DIRECT was an imperfect assessment of the unit, but this impacted all classes equally. The language of the DIRECT was slightly different than the language

of circuits that students learned in the course. At an advanced level, this may not be an issue, but for introductory students this may have caused confusion. For example, students were expected to understand voltage within circuits. On the test this was referred to in the context of “potential difference.” This is a phrase that students were familiar with, but it was not emphasized to the same extent that “voltage” was in the unit. It would have been helpful to have structured the unit using more similar terminology as the test. This is challenging as one also wants to avoid the mistake of teaching to the test. Fortunately, this threat did not affect any particular class more than another.

There are many ways in which this study could be improved upon in order to increase the validity of its findings. The threats of history and maturation should be minimized. The differentiated and non-differentiated activities must be refined and improved. The number of differentiated activities should be increased, and the strength of the interests by which the activities are differentiated needs to be increased. This initial study of differentiation by interest in a unit on basic electrical circuits did not provide results that affirmed the validity of differentiating by interest. This study did though lay the foundation for future, more sophisticated studies, which may reveal more optimistic insight into this methodology.

Appendix A Chi-Squared Test on Class Averages

H_0 : 1st Period Average = 3rd Period Average = 4th Period Average = 6th Period Average

H_1 : 1st Period Average ≠ 3rd Period Average ≠ 4th Period Average ≠ 6th Period Average

Chi-Squared Test of Grade Average

Period	Observed (O)	Expected (E)	Difference	(O-E)^2	(O-E)^2/E
1st	82.44	85.66	-3.22	10.36	0.12
3rd	86.87	85.66	1.21	1.46	0.02
4th	85.27	85.66	-0.39	0.15	0.00
6th	88.05	85.66	2.40	5.74	0.07
				X^2	**0.21**
$X^2_{(3)} = .21, p<.05$					

The critical X^2 value with 3 degrees of freedom at a 0.05 level of significance is 7.82. The obtained value of 0.21 is less than the critical value, hence the null hypothesis cannot be rejected, that the class grade averages is independent of class.

Appendix B Chi-Squared Test on Gender

Chi-Squared Test of Females by Class

H_0 : 1^{st} Period # Females=3^{rd} Period # Females=4^{th} Period # Females=6^{th} Period # Females

H_1 : 1^{st} Period # Females≠3^{rd} Period # Females≠4^{th} Period # Females≠6^{th} Period # Females

Chi-Squared Test of Females by Class

Period	Observed (O)	Expected (E)	Difference	(O-E)^2	(O-E)^2/E
1st	9	10	-1	1	0.10
3rd	14	10	4	16	1.60
4th	8	10	-2	4	0.40
6th	9	10	-1	1	0.10
				X^2	**2.20**
$X^2_{(3)} = 2.2, p<.05$					

The critical X^2 value with 3 degrees of freedom at a 0.05 level of significance is 7.82. The obtained value of 2.2 is less than the critical value, hence the null hypothesis cannot be rejected, that the number of females is independent of class.

Chi-Squared Test of Males by Class

H_0 : 1st Period # Males = 3rd Period # Males = 4th Period # Males = 6th Period # Males

H_1 : 1st Period # Males ≠ 3rd Period # Males ≠ 4th Period # Males ≠ 6th Period # Males

Chi-Squared Test of Males by Class

Period	Observed (O)	Expected (E)	Difference	(O-E)^2	(O-E)^2/E
1st	11	10	2	2	0.24
3rd	5	10	-5	20	2.13
4th	13	10	4	12	1.29
6th	9	10	-1	0	0.03
				X^2	**3.68**
$X^2_{(3)}$ = 3.68, p<.05					

The critical X^2 value with 3 degrees of freedom at a 0.05 level of significance is 7.82. The obtained value of 3.68 is less than the critical value, hence the null hypothesis cannot be rejected, that the number of males is independent of class.

Appendix C Chi-Squared Test on DIRECT Pre-Assessment Class Averages

H_0 : 1st Pd. DIRECT Avg. = 3rd Pd. DIRECT Avg. = 4th Pd. DIRECT Avg. = 6th Pd. DIRECT Avg.

H_1 : 1st Pd. DIRECT Avg. ≠ 3rd Pd. DIRECT Avg. ≠ 4th Pd. DIRECT Avg. ≠ 6th Pd. DIRECT Avg.

Chi-Squared Test of DIRECT Averages

Period	**Observed (O)**	**Expected (E)**	**Difference**	**(O-E)^2**	**(O-E)^2/E**
1st	5.83	4.67	1.16	1.35	0.29
3rd	3.47	4.67	-1.20	1.45	0.31
4th	4.95	4.67	0.28	0.08	0.02
6th	4.44	4.67	-0.24	0.06	0.01
				X^2	**0.63**
$X^2_{(3)} = .63, p<.05$					

The critical X^2 value with 3 degrees of freedom at a 0.05 level of significance is 7.82.

The obtained value of 0.63 is less then the critical value, hence the null hypothesis cannot be rejected, that the DIRECT pre-assessment average is independent of class.

Appendix D Summary of Possible Class Combinations

1st and 3rd	**DIRECT**	**Grade**
Average	4.69	84.60
Median	5.00	87.29
Skew	-0.05	-0.99
Std Dev	3.41	10.37
Males	15	
Females	24	
4th and 6th	**DIRECT**	**Grade**
Average	4.73	86.56
Median	4.00	91.06
Skew	0.73	-1.43
Std Dev	3.31	12.88
Males	22	
Females	17	
Difference Between Pairs	**DIRECT**	**Grade**
Average	-0.04	-1.96
Median	1.00	-3.77
Skew	-0.79	0.44
Std Dev	0.11	-2.51
Males	-7	
Females	7	

1st and 4th	**DIRECT**	**Grade**
Average	5.36	83.89
Median	5.00	90.04
Skew	0.27	-1.14
Std Dev	3.41	13.80
Males	23	
Females	18	
3rd and 6th	**DIRECT**	**Grade**
Average	3.94	87.44
Median	4.00	87.66
Skew	0.34	-0.26
Std Dev	3.12	8.50
Males	14	
Females	23	
Difference Between Pairs	**DIRECT**	**Grade**
Average	1.42	-3.55
Median	1.00	2.38
Skew	-0.06	-0.88
Std Dev	0.28	5.30
Males	9	
Females	-5	

1st and 6th	**DIRECT**	**Grade**
Average	5.18	85.10
Median	5.00	88.63
Skew	-0.04	-0.90
Std Dev	3.09	11.22
Males	19	
Females	19	
3rd and 4th	**DIRECT**	**Grade**
Average	4.29	86.03
Median	3.50	89.90
Skew	0.65	-1.49
Std Dev	3.53	12.18
Males	18	
Females	22	
Difference Between Pairs	**DIRECT**	**Grade**
Average	0.89	-0.93
Median	1.50	-1.27
Skew	-0.69	0.59
Std Dev	-0.44	-0.96
Males	1	
Females	-3	

Appendix E Electrical Interest Survey

Electricity Interest Survey

Please rate your responses

1. Working with and or learning about computer hardware.
Very Interested Interested Don't Care Uninterested Very Uninterested

2. Working on and or learning about how to repair cars (not including car stereo),
Very Interested Interested Don't Care Uninterested Very Uninterested

3. Figuring out how small household appliances work or fixing them.
Very Interested Interested Don't Care Uninterested Very Uninterested

4. Learning about how car/home stereos work.
Very Interested Interested Don't Care Uninterested Very Uninterested

5. Learning about Lightning and/or phenomena such as St. Elmo's Fire.
Very Interested Interested Don't Care Uninterested Very Uninterested

6. Working on/ learning about home electrical wiring.
Very Interested Interested Don't Care Uninterested Very Uninterested

7. Finding ways to conserve energy.
Very Interested Interested Don't Care Uninterested Very Uninterested

8. Learning about the history behind inventions.
Very Interested Interested Don't Care Uninterested Very Uninterested

9. Learning how electricity is produced.
Very Interested Interested Don't Care Uninterested Very Uninterested

10. Learning how telephones work.
Very Interested Interested Don't Care Uninterested Very Uninterested

11. Learning how radios work.
Very Interested Interested Don't Care Uninterested Very Uninterested

12. Learning how to avoid static electricity.
Very Interested Interested Don't Care Uninterested Very Uninterested

13. Learning how strobe lights work.
Very Interested Interested Don't Care Uninterested Very Uninterested

14. Learning how lasers work.
Very Interested Interested Don't Care Uninterested Very Uninterested

15. Learning about electrical safety.
Very Interested Interested Don't Care Uninterested Very Uninterested

16. Learning how the microwave works.
Very Interested Interested Don't Care Uninterested Very Uninterested

17. Learning how the internet works.
Very Interested Interested Don't Care Uninterested Very Uninterested

18. Learning how photocopiers work.
Very Interested Interested Don't Care Uninterested Very Uninterested

19. Learning how makeup works.
Very Interested Interested Don't Care Uninterested Very Uninterested

20. Learning how the brain works.
Very Interested Interested Don't Care Uninterested Very Uninterested

21. Learning how pacemakers work.
Very Interested Interested Don't Care Uninterested Very Uninterested

22. Learning about magnetism.
Very Interested Interested Don't Care Uninterested Very Uninterested

23. Learning how heat pumps work.
Very Interested Interested Don't Care Uninterested Very Uninterested

Appendix F First Differentiated Activity

Customized Review sheet

COMPREHENSIVE LESSON PLAN **DATE:** 3-10-06

GRADE LEVEL / SUBJECT/TOPIC: 11-12/Physics/Ohms Law Lab
STANDARDS ADDRESSED: PH 13a, b, c **DEVELOPED BY:** Amy McCarty
LENGTH OF LESSON: 1 class period **RESOURCES:** Jon Collins

PLANNING WHAT STUDENTS WILL:

KNOW (STANDARDS/CONTENT):

The student will know Ohm's law; series, parallel, and combined circuits; and circuit components including resistors and batteries.

UNDERSTAND (BIG IDEAS, ENDURING UNDERSTANDINGS):

- BIG IDEAS/CONCEPTS:
    - The arrangement of batteries in a circuit affects their total voltage and current.
    - The arrangement of resistors in a circuit affects their total resistance, voltage, and the current in a circuit. Ohms law describes this affect.
    - Different resistors can handle different levels of power.

- ESSENTIAL QUESTIONS (HOW OR WHY):
    - How does the arrangement of resistors in a circuit affect the current therein and how do we calculate how much power a resistor must handle?
    - How do we explain voltage, and how do we observe and maintain it in an electrical circuit?
    - How does the arrangement of resistors in a circuit affect the current therein?
    - What affects a material's resistance?

DO (SKILLS, PERFORMANCE):

- THE STUDENT WILL
    - Be able to explain voltage and current
    - Place batteries in parallel and series and calculate their equivalent voltage.
    - Place resistors in parallel and series and calculate their equivalent voltage.
    - Explain what affects a material's resistance.
    - Be able to configure specified resistor configurations in parallel and series
    - Calculate the level of power a resistor must be able to handle.

PLANNING PRE-ASSESSMENT:

TEACHER DOES:

- WHAT STRATEGY DID YOU USE?
  Gave students a questionnaire of their interests in items that are related to electricity. They rated their interest on a five point Likert scale.
- HOW WERE RESULTS USED TO DESIGN INSTRUCTION?
  Students were given review questions specific to their interests.

STUDENTS DO:

Respond to the questionnaire on a piece of paper that is turned into the teacher

PLANNING THE LEARNING EXPERIENCE:

INTRODUCTION (HOOK):

- TEACHER DOES:
  - Select several (5-10) topics that students have expressed an interest in and create word problems that relate their interests to their current study in circuits and resistors.
  - Create custom worksheets for each student with questions related to their interests. In order to keep all work equitable, make generic "replacement" questions for topics in which they are not interested.
  - Review Complex Circuits, which the class worked on previously.
  - Let students know that they will have a quiz in a week, review the topics so far that will be covered.
- STUDENTS DO:
  - Discuss what they expect will be on the quiz.

BODY:

- TEACHER DOES:
  - Explains that we need to review what we have studied up unto this point. Pass out the review sheet, and explain that the last seven problems are customized to their interests, but all students have equal amounts of work.
  - Monitors student's progress
  - Assists students as needed.
- STUDENTS DO:
  - Students work on the worksheet.

- IF DIFFERENTIATED:
    - WHAT(content, process, product)?
      Content – the questions were differentiated based on interest
    - HOW (readiness, interest, learning profile)?
      Interest – in electricity related topics
    - WHY (What identified need prompted you to differentiate this way)?
      Students have a difficult time seeing how resistors and circuits have any applicability to their daily lives. By differentiating by interest it is hoped that they will be exposed to how resistors are an integral part of their world.

CLOSURE:

- TEACHER DOES:
    - Let students know that they will have time on Monday or Tuesday to finish it up, and it will be due on Wed.

- STUDENTS DO:
    - Listen to the teacher

ASSESSMENT/CULMINATING PERFORMANCE

- DESCRIPTION:
  Students will work a differentiated worksheet that is customized to their individual set of interests.

- HOW DID YOU MEASURE:

    - CONTENT (know):
      Through their responses to the worksheet questions

    - UNDERSTANDINGS (related to big ideas):
      Through their responses to the worksheet questions

    - SKILLS (be able to do):
      Through their responses to the worksheet questions

© pending: Brimijoin &
Gould, 2005

Appendix G Interest-Based Review Questions

Lasers

In order to power a Helium Neon (HeNe) laser a large amount of voltage must be stored up in what is called a capacitor (we will learn more about these soon). The problem with capacitors is that they store charge, even after the power supply for the laser is turned off. In order to drain this charge people use a bleeder resistor that provides a path for the current to be grounded. These resistors must be at least 200MΩ and be able to handle 10kV.

> *You* are building a laser and unfortunately do not have a 200MΩ resistor. Instead you have a bunch of 50MΩ resistors. How many of these would you need to place in series in order to have your equivalent 200MΩ resistance? What is the max total current of this circuit (based on the maximum voltage)?

Phone

Phone lines carry our conversations (data) by using current. A phone line into your house has a voltage of 48V. A phone, when you pick it up off the hook, acts like 680Ω resistor. What would be the current across each phone if you had 3 in parallel? What would be the power across each phone?

Household Appliance/Household wiring

A hairdryer gets hot because it has essentially a long coiled up 7.5Ω resistor in it which heats up when current passes through it. The fan on a hairdryer pushes air over the heated resistor, which produces a blast of hot air. In the US, Hair dryers use 120V.

A curling iron has a heating element inside of it that is a 13Ω resistor, and it too, uses 120 volts.

The heating element of a coffee pot acts as a 24Ω resistor, and it too uses 120V.

When appliances are plugged into household outlets, they are in parallel. How much current is being used by each of these appliances? How much is being pulled by all of them when they are all plugged in and being used?

Cars

Cars run many of their functions on a parallel circuit, connected to the 12V battery.

Calculate the current, voltage and power dissipated across each of the following items, given their resistance:

Car Head Lights (2) - 5Ω each

The horn has a 2Ω resistor in it.

Your four speakers are each 2Ω

Stereo

Stereo speakers are wired up to amplifiers in series or in parallel. Amplifiers are constructed to "see" a certain number of ohms. If the ohms the amplifier sees falls below what it is capable of handling, the amplifier will shut off. If your amplifier's minimum number of ohms is 4 and you wire two midrange 4Ω speakers to it in parallel, will the amplifier see it? Show all work!

History

In 1914 GE Edison created a streetlight that was rated at 100 Candlepower. Candlepower (cp) described how bright a light was – today we use the measurement of Lumens. This 100cp bulb had a resistance of 18Ω, and was supplied with 120V of direct current.

If a street had 5 lamps using these bulbs, and they are in parallel what is the current pulled and power dissipated by each bulb and what is the total current pulled?

Computer

You bought a used computer and one day decided to look inside of it. Looking at the video card you see three resistors on it that are connected in parallel. Apparently someone had knocked off a resistor and manually replaced it with three in series. These three are 120Ω, 360Ω and 100Ω. What was the resistance of the resistor that they replaced?

Appendix H Non-Interest Based Review Questions

Laser Replacement

How many 300Ω resistors do you need to place in series in order to have an equivalent resistance of 30kΩ? If you run 250V through these resistors in series, what is the total current in the circuit?

Phone Replacement

If you have 3 725Ω resistors in parallel, connected to a 24V power supply, what is the current and power across each resistor?

Household Replacement

A 3Ω, 1.5Ω, and 2.4Ω resistor are all connected in parallel, across a 120V power source. How much current is going through each resistor, what is the total current through the circuit?

Cars Replacement

Calculate the current, voltage and power dissipated across the following resistors connected in parallel: 2Ω, 3Ω, 5Ω, 7Ω, 9Ω if they are connected to a 12v power supply.

Stereo Replacement

Two 36Ω resistors are connected in parallel. What is their equivalent resistance?

History Replacement

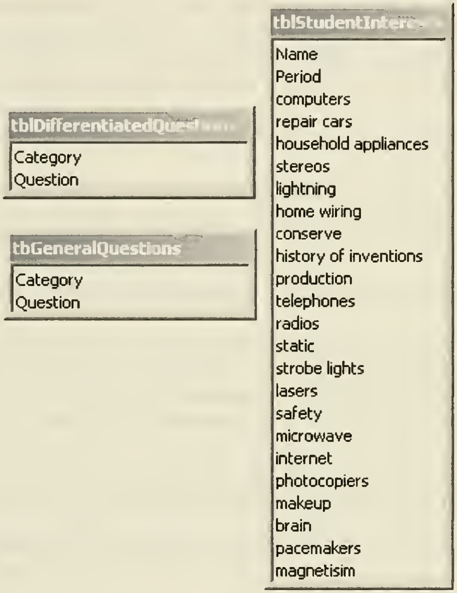
Find the individual current for each resistor, the power dissipated by each resistor, and the total current, if you have 7 4Ω resistors in parallel across a 12v power supply.

Computer Replacement

You have three resistors connected in parallel; they are 150Ω, 250Ω, and 3800Ω. What is their total resistance?

Appendix I Student Interests Database

The Student Interests Database was a simple Access database consisting of three tables. TblStudentInterests stores the name, class period and interests of each student. TblDifferentiatedQuestions and tblGeneralQuestions stores the differentiated and general questions, by their respective category.



tblDifferentiatedQues

Category
Question

tbGeneralQuestions

Category
Question

tblStudentInter

Name
Period
computers
repair cars
household appliances
stereos
lightning
home wiring
conserve
history of inventions
production
telephones
radios
static
strobe lights
lasers
safety
microwave
internet
photocopiers
makeup
brain
pacemakers
magnetisim

Appendix J Example Differentiated Worksheet

Coleman, Michael

1. Cars run many of their functions on a parallel circuit, connected to the 12V battery. Calculate the current, voltage and power dissipated across each of the following items, given their resistance:
   Car Head Lights (2) - 5Ω each
   The horn has a 2Ω resistor in it.
   Your four speakers are each 2Ω

2. A hairdryer gets hot because it has essentially a long coiled up 7.5Ω resistor in it which heats up when current passes through it. The fan on a hairdryer pushes air over the heated resistor, which produces a blast of hot air. In the US, Hair dryers use 120V.
   A curling iron has a heating element inside of it that is a 13Ω resistor, and it too, uses 120 volts.
   The heating element of a coffee pot acts as a 24Ω resistor, and it too uses 120V.

   When appliances are plugged into household outlets, they are in parallel. How much current is being used by each of these appliances? How much is being pulled by all of them when they are all plugged in and being used?

3. Two 36Ω resistors are connected in parallel. What is their equivalent resistance?

4. You bought a used computer and one day decided to look inside of it. Looking at the Video Card you see three resistors on it that are connected in parallel. Apparently someone had knocked off a resistor and manually replaced it with three in series. These three are 120Ω, 360Ω and 100Ω. What was the resistance of the resistor that they replaced?

5. Find the individual current for each resistor, the power dissipated by each resistor, and the total current, if you have 7 4Ω resistors in parallel across a 12v power supply.

6. If you have 3 725Ω resistors in parallel, connected to a 24V power supply, what is the current and power across each resistor?

7. In order to power a Helium Neon (HeNe) laser a large amount of voltage must be stored up in what is called a capacitor (we will learn more about these soon). The problem with capacitors is that they store charge, even after the power supply for the laser is turned off. In order to drain this charge people use a bleeder resistor that provides a path for the current to be grounded. These resistors must be at least 200MΩ and be able to handle 10kV.

   You are building a laser and unfortunately do not have a 200MΩ resistor. Instead you have a bunch of 50MΩ resistors. How many of these would you need to place in series in order to have your equivalent 200MΩ resistance?

   What is the max total current of this circuit (based on the maximum voltage)?

Appendix K Second Differentiated Activity

Customized Group Problems

COMPREHENSIVE LESSON PLAN **DATE:** 3-15-06

GRADE LEVEL / SUBJECT/TOPIC: 11-12/Physics/Differentiated Ohms Law Lab
STANDARDS ADDRESSED: PH 13a, b, c **DEVELOPED BY:** Amy McCarty
LENGTH OF LESSON: 1 class period **RESOURCES:** Jon Collins

PLANNING WHAT STUDENTS WILL:

KNOW (STANDARDS/CONTENT):

The student will know Ohm's law; series, parallel, and combined circuits; and circuit components including resistors and batteries.

UNDERSTAND (BIG IDEAS, ENDURING UNDERSTANDINGS):

- BIG IDEAS/CONCEPTS:
  - The arrangement of batteries in a circuit affects their total voltage and current.
  - The arrangement of resistors in a circuit affects their total resistance, voltage, and the current in a circuit. Ohms law describes this affect.
  - Different resistors can handle different levels of power.

- ESSENTIAL QUESTIONS (HOW OR WHY):
  - How does the arrangement of resistors in a circuit affect the current therein and how do we calculate how much power a resistor must handle?
  - How do we explain voltage, and how do we observe and maintain it in an electrical circuit?
  - How does the arrangement of resistors in a circuit affect the current therein?

DO (SKILLS, PERFORMANCE):

- THE STUDENT WILL
  - Be able to explain voltage and current
  - Place batteries in parallel and series and calculate equivalent voltage.
  - Place resistors in parallel and series and calculate equivalent voltage.
  - Be able to explain what affects a material's resistance.
  - Be able to configure specified resistor configurations in parallel and series
  - Calculate the level of power a resistor must be able to handle.

PLANNING PRE-ASSESSMENT:

TEACHER DOES:

- WHAT STRATEGY DID YOU USE?
  Gave students a questionnaire of their interests in items that are related to electricity. They rated their interest on a five point Likert scale.

- HOW WERE RESULTS USED TO DESIGN INSTRUCTION?
  Students were given a lab that was specific to one of their interests.

STUDENTS DO:

Respond to the questionnaire on a piece of paper that is turned into the teacher

PLANNING THE LEARNING EXPERIENCE:

INTRODUCTION (HOOK):

- TEACHER DOES:
  - Select several (3) topics that students have expressed an interest in and create labs that relate one of their interests to Ohm's Law. Labs are primarily word problem based, but may have some supporting lab equipment.
  - Assign students to groups based on their interests.
  - Let students know that they are assigned to groups based on their interests. Assure them that although these are challenging problems, the teacher will help them through it.
  - Tell students their groups and where they will sit.
  - Let students move into their groups and then pass out the lab
  - Go around to each group and get them started.
- STUDENTS DO:
  - Listen to the instructions
  - Move into their assigned groups

BODY:

- TEACHER DOES:
  - Assists students through the lab as needed.
  - If students finish up early ask them to create a review sheet of what will be on the quiz.

- STUDENTS DO:
  - Work through the lab
  - Create a review sheet if time remains

- IF DIFFERENTIATED:
  - WHAT(content, process, product)?
    Process – All students are working on the same ideas (Ohm's Law) but they are all doing it in different contexts.
  - HOW (readiness, interest, learning profile)?
    Interest – in an electricity related topic.
  - WHY (What identified need prompted you to differentiate this way)?
    Students have a difficult time seeing how resistors and circuits have any applicability to their daily lives. By differentiating by interest it is hoped that they will be exposed to how resistors are an integral part of their world.

CLOSURE:

- TEACHER DOES:
  - Let students know that tomorrow we will have a quiz review

- STUDENTS DO:
  - Listen to the teacher

ASSESSMENT/CULMINATING PERFORMANCE

- DESCRIPTION:
  Students will work a differentiated lab that is customized to one of their individual interests.

- HOW DID YOU MEASURE:
  - CONTENT (know):
    Through their responses to the lab questions
  - UNDERSTANDINGS (related to big ideas):
    Through their responses to the lab questions
  - SKILLS (be able to do):
    Through their responses to the lab questions

Appendix L Differentiated Group Problems

Car Trouble, Stereo Problems and Lasers

Car Trouble

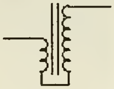
You have been having car problems lately, which strangely enough all deal with different kinds of resistors. Fortunately, you are just finishing up studying resistors in your physics class, so you are in a good position to fix these problems!

Car Problem # 1
When you start your car (turning your ignition all the way to the "start" position) your engine starts up, but as soon the ignition key goes to "run", the car dies.

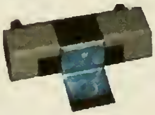
You talk to a mechanic friend of yours and he says that it sounds like the ballast resistor is bad. He tells you that when you start your car up it needs extra current going through the ignition so it is routed straight from your battery to your ignition. Once it gets gong though (when you turn the key back to "run") it doesn't need as much current, so it routes the electricity through the ballast resistor before it goes into the ignition.

You find your ballast resistor and see that is it corroded. You take it out and see that it is a 2.5Ω resistor. The voltage that is supplied by your battery to your ignition is 12volts.

Here is the symbol, and a picture of a coil ignition:



Here is a picture of a ballast resistor:
Ballast resistors use the same schematic symbol as normal resistors.



1. **Neatly draw and label how the battery, ballast resistor and ignition are connected when your key is in the "start" position.**

2. **Neatly draw and label how the battery, ballast resistor and ignition are connected when your key is in the "run" position.**

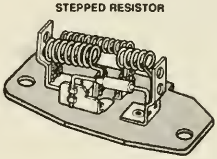
3. **What is the current that goes to your ignition through the ballast resistor? Show all work!**

4. **What is the minimum power rating of this resistor? Show all work!**

You don't feel like replacing the ballast resistor, so you simply take it out and bypass it (so there is no resistor, and it always gets as much current as when you first start the car up). Your car runs fine for a while, but then your ignition breaks. **Why do you think this is? What happens when current flows through wires? What affect does it have on it?**

Car Problem #2

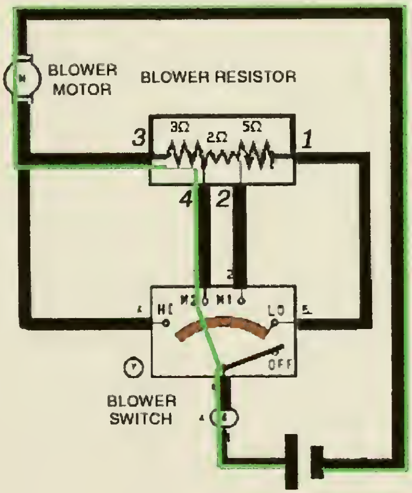
You get into your car, and it's a cold winter day. You turn on your heater fan and find that it won't run on the low or medium settings, only on the high setting.



Talking with your mechanic friend, he tells you it sounds like the stepped resistor in your heater knob is broke. You look up stepped resistor on the internet and find that it is a set of three resistors (they are different looking then what you normally see as resistors, they are just coils of wire with varying resistances)

You look on the internet some more and find that the way they work is as you turn your blower knob either one, two, or all three of the resistors will be connected in series. See, the diagram below shows you that if the blower needle is turned to M2 then current goes through just one resistor (the gray line) When the blower is on LO then current goes through all of the resistors (following the path of wire #1).

5. **Trace the path of the current if the blower is on "M1". How many resistors does it go through?**



For each of the settings answer the following questions, assuming that the blower is powered by the 12V car battery.

6. **For each setting Lo, M1, M2, Hi what resistors does the current go through?**

7. **For each setting Lo, M1, M2 what is the total resistance?**

8. **For each setting Lo, M1, M2 how much current goes to the blower?**

Problem #3

You decide to trick your ride with some under the car neon lights. These lights each need 12v to operate and normally hook up directly to your car battery. You are having a hard time running your wire all the way to the battery so you decide to put each of the lights in series with each of your headlights (which act like 2Ω resistors). Just before you get ready to do this your friend stops by and sees what you are about to do. She thinks that you are making a mistake. "How so?" you ask her. She poses two questions for you to ponder over.

9. **If you wire your neon lights in series with your headlights can you turn them on when your headlights are not on, or visa versa? Why or why not?**

10. **How many volts is your neon light going to be getting? Is that enough for it to work?**

Stereo Problems

Building a Portable Amplifier

You are building your own little portable amplifier to use with your iPod. The amp needs .1A. Your power supply provides 1V.

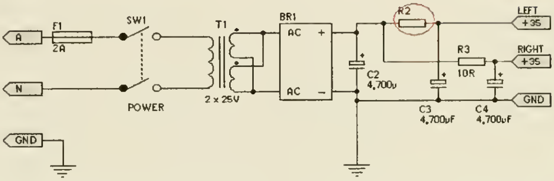


Figure 1: Electrical Schematic of Power Supply for Portable Amp

1. **What size resistor can you use to get the current to the value that you need? (No, you do not need to use the schematic above to solve this!)**

2. **What does its power rating need to be?**

The output resistor from your amp to your speakers should be 120 Ohm and rated at 2 Watts. The output resistor is circle din the diagram below.

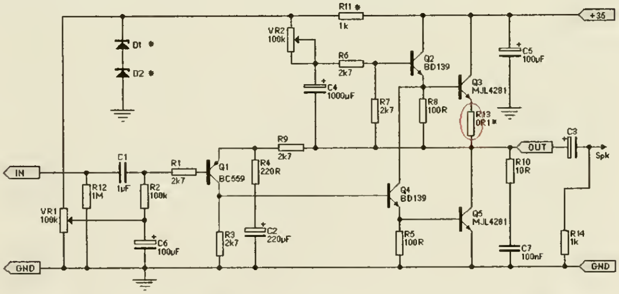


Figure 2: Electrical Schematic of Portable Amp, with Output resistor circled

3. **What is the current and voltage that will go through the output resistor?**

You have two 100Ω resistors.

4. **If you put them in parallel, can they replace the 120Ω /2W resistor?**

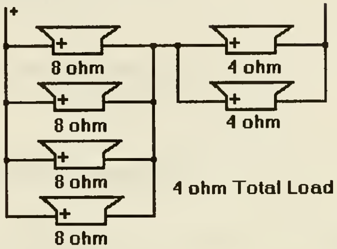
You have two 240Ω resistors.

5. **If you put them in parallel, can they replace the 120Ω /2W resistor?**

6. **What power rating must they have?**

Wiring up Speakers

You are wiring up your speakers to your home amplifier. They are connected to a 24V power supply. This is how you wire them up:

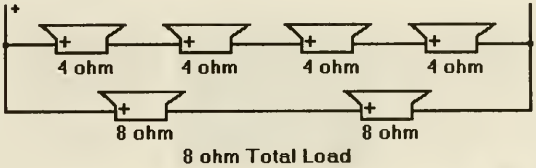


1. **What is the total resistance?**

2. **What is the power across each of the 8Ω speakers?**

3. **What is the power across each of the 4Ω speakers?**

You help your friend wire up her speakers, and this is how you configure them:



4. What is the total resistance?

5. What is the power across the 8Ω speakers?

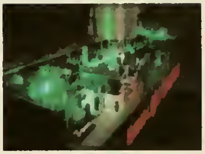
6. What is the power across the 4Ω speakers?

Ideally, you would like for the power across each resistor to be the same. Another friend of yours has two 8Ω speaker, and one 16Ω speaker.

7. How could your friend arrange his speakers so that they all have the same power?

Lasers

DANGER
LASER LIGHT- AVOID DIRECT EYE EXPOSURE
CLASS II, IIIa, IIIb, IV LASER PRODUCTS



DANGER
LASER LIGHT- AVOID DIRECT EYE EXPOSURE
CLASS II, IIIa, IIIb, IV LASER PRODUCTS

You have read on the internet that the brightness of some lasers doesn't relate directly with the amount of current sent to them. You decide to test this and see if it holds true for a little red laser that you recently bought.

Figure 31: Your Laser

You are going to change the current going to you laser by changing the configuration of resistors that are between the battery and the laser. You will test the strength of the laser light by using a photoresistor.

> **Photoresistors** are special resistors that, the more light that shines on them, the more resistance they have.

You have 4 resistors. You are going to come up with five different configurations for your resistors (always using all of them), in order to create five different total currents (I_t). You will hook them up to your laser that must be pointed at the photoresistor and read the resistance of the photoresistor with your ohmmeter.

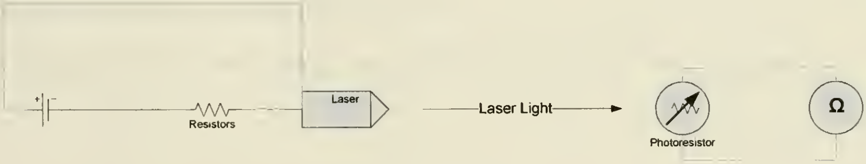


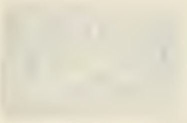
Figure 1: Laser setup

1. **Neatly draw and label the schematic of each of your five resistor configurations.**

2. **Calculate the total resistance and current for each of your configurations.**

3. **Plot the calculated current versus the photoresistor's resistance.**

4. **Is the correlation between current and the strength of the laser light linear? Why or why not?**



Appendix M Control Group Lab

Name:_______________

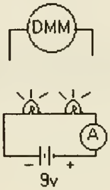
Lights Lab

Purpose To determine the effects of parallel and series circuits as well as practice following a schematic.

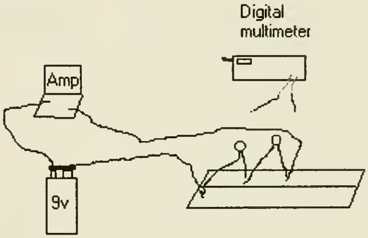
Procedure:

1. Set up the following circuit**. Note: do not attach the battery until step two**.

Schematic



Actual



2. Attach the battery
3. Use the DMM to find the voltage across each of the lights.

V across 1st light: _________

V across 2nd light _________

Total V across both lights: _________

4. Record the current:________

5. Now pull one of the wires attached to the first light out, what happens to the other light?

6. Now disconnect the battery from its wires.

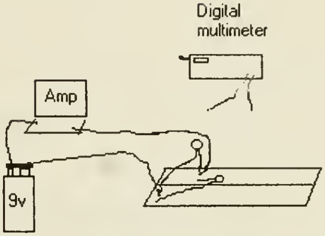
7. Calculate the total power being used. Hint use the equation p=vi.

7. Are the lights in series or parallel?

8. Use the equation v=ir to find the hot resistance of the first light.

9. Use the equation v=ir to find the hot resistance of the second light.

10. Now disassemble the previous circuit and assemble the following one. Remember do not connect the battery yet!



11. Draw a schematic of the circuit. The lights should be in parallel with the battery.

12. Use the DMM to find the voltage across each the lights.

V across 1st light: ________

V across 2nd light ________

13. Record the current:________

14. Now pull one of the wires attached to the first light out, what happens to the other light?

15. Now disconnect the battery from its wires.

16. Calculate the total power being used. Hint use the equation p=vi.

17. In this circuit the current is split between the two lights. Use the voltage measured across the lights and the hot resistance from the first part to determine the current in each of the lights. Hint use the formula v=ir.

18. Explain in terms of circuits why with some strands of Christmas lights when you pull one out they all go out and in others this does not happen.

19. How is your house wired in series or parallel?

20. When does more current flow in series or parallel?

21. When were the bulbs the brightest in series or parallels?

22. A series circuit consist of 4 resistors connected in series: 12Ω, 28Ω, 32Ω, and a 38Ω to a battery. What is the total equivalent resistance?

23. Assume that the previous resistors were put into parallel, what would the total resistance be then?

24. If circuit in #21 was connected to a 9 volt battery what would the current be?

25. If the circuit in # 22 was connected to a 9 volt battery what would the total current be?

25. What would be the current thorough each resistor?

Appendix N T-Test of DIRECT Improvement

H_0 : Control Group DIRECT Improvement = Experimental Group DIRECT Improvement

H_1 : Control Group DIRECT Improvement < Experimental Group DIRECT Improvement

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Difference	Control	36	7.78	3.432	.572
	Experimental	30	6.57	3.148	.575

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Difference	Equal variances assumed	.494	.485	1.482	64	.143	1.211	.817	-.422	2.844
	Equal variances not assumed			1.494	63.379	.140	1.211	.811	-.409	2.831

Results: $t_{(64)} = 1.482$, $p>0.05$

The critical one-tailed t-value with 60 degrees of freedom (used rather that 64 which is not in the table) at a 0.05 level of significance is 1.671. The obtained value of 1.482 is less than the critical value. Hence the null hypothesis cannot be rejected, the improvement shown by students on the DIRECT must be assumed to be independent of grouping.

Appendix O Chi-Squared Test on Average Absences per Class Period

H_0 : 1st Avg. Absences = 3rd Avg. Absences = 4th Avg. Absences = 6th Avg. Absences

H_1 : 1st Avg. Absences ≠ 3rd Avg. Absences ≠ 4th Avg. Absences ≠ 6th Avg. Absences

Chi-Squared Test of Grade Average

Period	**Observed (O)**	**Expected (E)**	**Difference**	**(O-E)^2**	**(O-E)^2/E**
1st	1.75	1.54	0.22	0.05	0.03
3rd	1.58	1.54	0.04	0.00	0.00
4th	1.20	1.54	-0.34	0.11	0.07
6th	1.61	1.54	0.08	0.01	0.00
				X^2	**0.11**
$X^2_{(3)} = .11, p<.05$					

The critical X^2 value with 3 degrees of freedom at a 0.05 level of significance is 7.82. The obtained value of 0.11 is less than the critical value, hence the null hypothesis cannot be rejected, and the average absences are assumed to be independent of class.

Appendix P Mann-Whitney U Test on Select Class DIRECT Scores

H_0 : 4th Period DIRECT Score Improvement = 6th Period DIRECT Score Improvement

H_1 : 4th Period DIRECT Score Improvement ≠ 6th Period DIRECT Score Improvement

Ranks

	Period	N	Mean Rank	Sum of Ranks
Difference	4.00	20	18.80	376.00
	6.00	14	15.64	219.00
	Total	34		

Test Statistics[b]

	Difference
Mann-Whitney U	114.000
Wilcoxon W	219.000
Z	-.922
Asymp. Sig. (2-tailed)	.356
Exact Sig. [2*(1-tailed Sig.)]	.377[a]

a. Not corrected for ties.

b. Grouping Variable: Period

The critical p-value of a two tailed Mann-Whitney U test where $n_1 = 20$ and $n_2 = 14$ at a 0.05 level of significance is 0.377. This greater than 0.05 hence the null hypothesis cannot be rejected. The score improvements are assumed to be independent of class.

Bibliography

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D. & Wieman, C. E. (n.d.). *A new instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey*. Retrieved December 4, 2004, from University of Colorado, Physics Education Technology Web site: http://cosmos.colorado.edu/phet/survey/CLASS/CLASS%20I.pdf

Alexander, P. A., Jetton, T. L., & Kulikowich, J. M. (1995, December). Interrelationship of knowledge, interest, and recall: Assessing a model of domain learning [Electronic version]. *Journal of Educational Psychology, 87,* 559-575.

Bae, Y., & Smith, T. M. (1997). *Women in mathematics and science* (Report No. NCES-97-982). Washington, DC: National Center for Education Statistics. (ERIC Document Reproduction Service No. ED412137).

Dewey, J. (1913). *Democracy and education.* Retrieved November 17, 2005, from Project Gutenberg Web site: http://www.gutenberg.org/dirs/etext97/dmedu10.zip

Donahue, D. M. (1993). Serving students, science, or society? The secondary school physics curriculum in the United States, 1930-65 [Electronic version]. *History of Education Quarterly, 33,* 321-352.

Edelson, D.C., Joseph, D. M., (2001). *Motivating active learning: A design framework for interest-driven learning.* Manuscript submitted for publication. Retrieved April 7, 2006, from the Design Based Research Collective Web site: http://www.designbasedresearch.org/reppubs/edelson-joseph.pdf

Engelhardt, P.V., & Beichner, R.J. (1997). *Determining and Interpreting Resistive Electric Circuits Concepts Test . Version 1.2.* North Carolina State University, Department of Physics, Raleigh, NC.

Engelhardt, P.V., & Beichner, R.J. (2003). Students' understanding of direct current resistive electrical circuits [Electronic version]. *American Journal of Physics, 72,* 98-115.

Hake, R.R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses [Electronic version]. *American Journal of Physics*, *66*, 64-74.

Hidi, S. (1990). Interest and its contribution as a mental resource for learning [Electronic version]. *Review of Educational Research, 60,* 549-571.

Howe, M.J.A. (1998). *Principles of abilities and human learning.* Hove, East Sussex: Psychology Press. Retrieved April 21, 2006, from the NetLibrary database: www.NetLibrary.com

Knight, R. D. (2004). *Five Easy Lessons: Strategies for Successful Physics Teaching.* San Francisco: Addison Wesley.

Krapp, A. (2003). Interest and human development: An educational-psychological perspective [Electronic version]. In L. Smith, C. Rogers & P. Tomlinson (Eds.), *BJEP Monograph Series II: No. 2. Development and Motivation, 1,* (pp. 57-84). Leicester, England: The British Psychological Society.

Millikan, R. A. (1950). *The Autobiography of Robert A. Millikan.* New York: Prentice-Hall.

Payne, D.A. (2003). *Applied educational assessment second edition.* Belmont, CA: Wadsworth Group.

Peters, J.T. (1941). A physics teacher faces his problems. *School Science and Math, 41,* 559-567.

Perkins, K.K., Adams, W.K., Pollock, S.J., Finkelstein, N.D. & Wieman, C.E. (n.d.). *Correlating student beliefs with student learning using the Colorado learning attitudes about science survey*, Retrieved April 7, 2006, from University of Colorado, Physics Education Technology Web site: http://www.colorado.edu/physics/phet/web-pages/publications/Perkins_PERC_revisedfinal.pdf

Renninger, K. A. (1992). Individual interest and development: Implications for theory and practice. In K. A. Renninger & A. Krapp (Eds.), *The role of interest in learning and development*. (pp. 361-395). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Schiefele, U., Krapp, A., & Winteler, A. (1992). Interest as a predictor of academic achievement: A meta-analysis of research. In K. A. Renninger & A. Krapp (Eds.), *The role of interest in learning and development*. (pp. 183-212). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Skager, R. W., Bussis, A. M., & Schultz, C. B. (1965). Comparison of information scales and like-indifferent-dislike scales as measures of interest. *Psychological Reports, 16*, pp. 251(10).

Swartz, C. (1991). The physicists intervene. *Physics Today*, *44*(9), 22-28.

Tobias, S. (1994). Interest, prior knowledge, and learning [Electronic version]. *Review of Educational Research*, *64*, .37-54.

Tomlinson, C. A., & Allan, S. D., (2000). *Leadership for differentiating schools & classrooms*. Alexandria, VA: Association for Supervision and Curriculum Development.

8270 6250 7
10/25/06 VA